Helios Mission Support

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With Helios-1 completing its third perihelion and Helios-2 passing its first perihelion, much valuable scientific data were obtained about the inter-Earth-Sun regions. The first solar occultation of Helios-2 is anxiously awaited as the next important mission phase. Preparations are underway for Helios-2 first entry into solar occultation in mid-May 1976. This article reports on the activities around Helios-1 and -2 perihelions.

I. Introduction

This is the ninth article in a series that discusses Helios-1 and Helios-2 mission support. The previous article (Ref. 1) reported on Helios-2 prelaunch and launch activities, spacecraft maneuvers, Helios-1 and Helios-2 cruise operations, and DSN-STDN cross-support status. This article covers Helios-1 third perihelion, Helios-2 first perihelion, spacecraft TWT and ranging anomalies, Helios DSN-STDN cross-support, and DSN performance.

II. Mission Operations and Status

A. Helios-1 Operations

As reported in the last Helios Progress Report (Ref. 1), the Helios-1 spacecraft ranging system failed to respond on 28 January 1976. Ranging became possible again on 17 March 1976 due to higher spacecraft temperature. The problem was, as suspected, associated with the spacecraft ranging transponder temperatures, and corrected itself as the spacecraft approached the Sun. (This problem is explained more fully in this article, Subsection IV-B.)

On day-of-year (DOY) 82 (22 March 1976), seven days before the third perihelion, a spacecraft anomaly occurred. At approximately 0726 GMT, during a station gap, Experiment 1 switched OFF. Both high voltages for Sensor A and Sensor B of Experiment 10 dropped to zero, and the read-in mode (DM4, FM3—which should have covered the gap) stopped. The cause of this anomaly is undetermined at this writing.

A similar incident occurred on DOY 82 in 1975 (23 March 1975) with Experiment 10 (high-voltage breakdown). The conclusion then was that an internal spike into or out of Experiment 10 was the cause of the problem. Both Experiments 1 and 10 were reconfigured, and the memory checked. All are presently performing correctly.

On Monday, 29 March 1976 at 1600 GMT (Launch +475 days), Helios-1 successfully passed its third perihelion with a minimum distance from the Sun of 0.31 AU, and at a distance from the Earth of 0.933 AU. The temperatures experienced by the spacecraft were slightly higher than those during the second perihelion. The spacecraft system's performance was excellent, and the Helios Project Office expressed confidence in obtaining a fourth perihelion without problems.

The switch to the high-power mode was successfully performed on DOY 97 (6 March 1976) at 0805 GMT. The spacecraft is presently using its high-gain antenna, and is spinning at 60.235 rev/min.

B. Helios-2 Operations

In early February 1976, while Helios-2 was in its cruise phase, the spacecraft team detected a slight decrease in the solar aspect angle. To keep the spin axis of the spacecraft within one degree around the nominal position, two attitude correction maneuvers were performed on DOY 51 (20 February 1976) and DOY 55 (24 February 1976). The solar aspect angle was changed from 89.0 degrees to 89.5 degrees.

Helios-2 was transmitting from traveling wave tube (TWT)-1 on high power when, on DOY 99 (8 April 1976), the hard limit for the helix (tube element) current was reached. When the limit was reached, TWT-1 was switched to the medium power mode. All TWT-1 parameters for medium power mode were normal, but after careful analysis of the situation the transmitter was commanded to TWT-2, medium power. It was also decided by the Spacecraft Operations Team that Helios-2 would remain in medium power mode until the end of the primary mission. TWT-2 has subsequently (20 April) been commanded to the high-power mode and experienced the "out of limits" helix current condition also. (The TWT was allowed to remain in high power for only 45 minutes.) Presently, the Helios-2 spacecraft is transmitting from TWT-2, medium power. It is unclear at this time if the higher temperatures now being felt by the spacecraft have any relation to the helix current increase.

Helios-2 passed its first perihelion on Saturday, 18 April 1976, at 0229 GMT (Launch +92 days) with a minimum distance from the Sun of 0.29 AU. The spacecraft was operating in the medium power mode, high-gain antenna. The Helios-2 spacecraft came nearly 3-million kilometers (2-million miles) closer to the Sun than its predecessor, Helios-1, and experienced approximately 10% more heat. All spacecraft subsystems and experiments performed well during the perihelion, and continue as the spacecraft approaches its first solar superior conjunction. Data returned by the two Helios spacecraft will be correlated with data from Pioneers 10 and 11 (in the outer reaches of the solar system).

C. Spaceflight Tracking and Data Network (STDN) Cross-Support

Meetings were held on 18 and 19 March 1976 at Goddard Space Flight Center (GSFC) with GSFC and JPL personnel in attendance. The purpose of these meetings was to discuss the DSN-STDN cross-support for the Helios Project and to finalize the DSN-STDN Interface Agreement. Also, some operational problem areas that required attention were discussed. A better understanding of each network's problems, capabilities, and limitations was an important aspect of these meetings.

THE DSN-STDN Interface Agreement for Cross-Support for Project Helios was distributed on 15 April 1976. The purpose of this document is to establish the necessary interfaces and operational plans to provide tracking of the Helios-1 and Helios-2 spacecraft by the STDN and analog recording of Helios telemetry data.

The STDN-Madrid station has been providing telemetry recording cross-support for the Helios-1 spacecraft since 15 January 1976. On 9 April, the downlink signal level reached recording threshold and the Madrid support was suspended until the link margin comes above threshold again (approximately September/October 1976).

The Goldstone STDN station, previously down for a major reconfiguration, became operational on 6 April, after an engineering test was conducted. The results at the time of the test were inconclusive because the analog magnetic tape recordings could not be properly evaluated in real-time. Results of STDN (MIL-71)[1] reduction/comparisons of the Goldstone STDN and Echo (DSS 12) analog magnetic tape recordings are not yet complete. Helios passes since the test have been supported from the Goldstone STDN station. The DSN will continue to request cross-support from this STDN station until recording threshold is reached (estimated for mid-May 1976).

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[1] DSN equipment located at S/C Compatibility Test Station at MILA, Cape Canaveral.

An engineering evaluation of sending in real-time a STDN receiver baseband output (i.e., the data modulated 32-kHz Helios telemetry subcarrier) to a DSN station via intersite microwave is now in progress. The purpose of this test is to determine if the losses we presently experience in the " STDN/record/STDN(MIL-71) reduction " mode can be minimized, therefore increasing the data quantity and quality to be derived from the STDN cross-support. This evaluation is expected to be completed during May 1976.

D. Actual Tracking Coverage Versus Scheduled Coverage

This report covers tracking activities for a 65-day period for the Helios-1 and Helios-2 spacecraft, from 6 February through 11 April 1976. Operations during this period include cruise, inferior conjunctions of both spacecraft, and Helios-1 third perihelion.

Helios-1, sharing equal priority with Pioneers 10 and 11, was tracked 125 times for a total of 704 hours. The Helios-1 allocation was approximately one-third of the total Pioneer/Helios-1 allotment. This represents a 9 percent increase in the number of passes, and 70 percent increase in hours tracked. The average pass duration continues to linger around 5.6 hours. Overlapping view periods and heavy demands on the Network, causing split-pass coverage, is responsible for this figure. (This type of tracking coverage for extended mission spacecraft is likely to continue.) Owing to critical phases of the Helios-1 mission (inferior conjunction and third perihelion), the 64-meter subnetwork accounted for 381 hours, or approximately 54 percent of the total of 704 hours. This represents an increase of 232 hours or 150 percent increase in 64-meter coverage.

In addition to the DSN tracking coverage, the Spaceflight Tracking and Data Network, controlled from the Goddard Space Flight Center (GSFC), also tracked the Helios-1 spacecraft 18 times for a total of 79 hours. Analog tape recordings of the spacecraft telemetry data are processed at STDN (MIL-71) and sent to JPL via High-Speed Data Line (HSDL) to be incorporated in the Master Data Record (MDR), which is sent to the Helios Project for use in the production of Experimenter Data Records.

Helios-2, enjoying equal priority with the two Viking spacecraft, is presently in prime mission phase approaching its first solar encounter (perihelion). The total tracking coverage shared between the two Viking and Helios-2 spacecraft was 574 passes, equaling 5248 hours. The Helios-2 portion was approximately 45 percent of the total, or 246 passes and 2149 hours of tracking coverage. This represents 100% of required DSN coverage for the Helios-2 spacecraft.

The Spaceflight Tracking and Data Network tracked Helios-2 only once during this period for 4 hours. This track was in parallel with DSN coverage and was part of an engineering evaluation of the Goldstone STDN station performance.

After the prime mission phase of Helios-2 (approximately mid-May 1976), tracking priority will equal that of Helios-1 and Pioneers 10 and 11. DSN tracking coverage is expected to decrease during the next reporting period due to this priority change and increased Viking planetary activities.

III. Special Helios Tests

The Helios-1 spacecraft ranging system failed on 28 January 1976 (Ref. 1). In an attempt to find the cause, a special Helios-1 ranging channel test was performed on 5 March 1976 at DSS 14. For this experiment, the ranging uplink channel was modulated continuously with a coherent 250-kHz sine wave instead of the normal pseudo-random code ("square wave"). The Precision Signal Power Measurement (PSPM) equipment was then used to look for any sidebands at the fundamental (S-band frequency minus 250 kHz) first and second harmonics (see Fig. 1). The visual interpretation of the CRT-displayed power spectrum showed no ranging sidebands. The solution to the Helios-1 spacecraft ranging problem had to wait until 17 March (see Subsection IV-B, this report).

On behalf of Helios passive experiments 11 and 12 (Celestial Mechanics and Faraday Rotation, respectively) the Helios Project requested that the Mu-2 ranging system be used at the Goldstone Mars Station (DSS 14) instead of the Planetary Ranging Assembly (PRA) during perihelion and occultation phases of Helios-1 and Helios-2. At very small Sun-Earth-Probe (SEP) angles, the Mu-2 system has greater accuracy than the PRA. An implementation schedule was formulated (see Fig. 2) and set in motion. All milestones were successfully met and the Mu-2 became the prime ranging equipment for Helios and Viking at DSS 14, and will continue to be prime until January 1977.

IV. DSN System Performance for Helios

A. Command System

Helios command activity has continued to rise during this report period. With Helios-2 still in prime mission and Helios-1 experiencing its third perihelion, this increase came as no surprise. An 83% increase, or 11,085 commands, were sent to the two Helios spacecraft during the months of February and March. This boosts the cumulative command totals to 31,376 for Helios-1 and 9,059 for Helios-2. Two Command System aborts occurred during February—none in March. The first abort was caused by a procedural error. Command modulation was turned off 10 minutes early. It occurred on 8 February with the Helios-1 spacecraft.

The second Command System abort, on 27 February at DSS 61 with Helios-2, was due to a loose pin in the configuration register card file. The Command System was inoperative for 31 minutes while the repair was made.

The Command System downtime due to equipment problems was 24.7 hours for the two-month period. Four outages exceeded one hour, the longest being 7 hours and 50 minutes. The Command Modulator Assembly (CMA) failed early in the pass and could not be restored. This downtime is significantly higher (approximately 400%) than the last report period. However, because of Network loading, redundant stations and/or equipment strings not being available in some cases, longer than normal Command System downtimes resulted.

B. Tracking System

Solutions to two significant ranging anomalies, reported in the last Helios Progress Report (Ref. 1) were discovered during this report period. It had been noted earlier (first observed on 12 December 1975 while ranging over the Weemala Station at Tidbinbilla, Australia (DSS 42) on Helios-1) that sometimes the pseudo digital range versus integrated doppler (DRVID) values for a series of range acquisitions during a single pass would differ from each other by a multiple of 1024 range units (the half-period of the clock component). With analysis, it was decided that this could be caused by the station transmitting a ranging code inverted from what it should be. This theory was confirmed by observing the failure in real time and confirming that the station had inadvertently instructed the Planetary Ranging Assembly (PRA) to send an inverted code. The Block III and Block IV systems are inverted in respect to each other, as are the Helios and Viking ranging codes. This understandably results in a confusing operational situation, complicated by "Load and Go" countdowns.

The second ranging problem was the Helios-1 spacecraft loss of ranging capabilities observed on 28 January 1976 (Ref. 1). This was the second time that Helios-1 spacecraft ranging system had ceased to respond. The Spacecraft Analysis Team theorized that the failure was associated with spacecraft temperature. On DOY 77 (17 March 1976), it was possible again to perform ranging on Helios-1. In analyzing the history of the Helios-1 ranging performance, the spacecraft team stated that the ranging transponder does not function when the Very Stable Oscillator (VSO) temperature is between 5°C and 18°C. The performance is good above and below this temperature region.

Two reports on the "Effect of the Sun on Doppler Noise" were distributed in February by the DSN Operations Analysis Tracking Subgroup. The first describes the analysis performed on the data collected during the second Helios-1 superior conjunction. The second report presents the somewhat surprising hypothesis that the solar contribution to doppler noise is proportional to the total electron content along the station-spacecraft line-of-sight. The results of this latter study are found elsewhere in this DSN Progress Report, entitled, "Doppler Noise Considered as a Function of the Signal Path Integration of Electron Density" (Ref. 2).

C. Telemetry System

The DSN has considerable data on 64-meter station performance when tracking spacecraft in angular proximity of the Sun, but little was known of 26-meter performance in this region. The Helios-1 and Helios-2 inferior conjunctions (March 14 and March 24, respectively) presented an excellent opportunity to gather this kind of data. These data will be added to other data base information to formulate a telemetry performance model under high solar noise conditions. The objective is to increase reliability of telemetry predictions during low Sun-Earth-Probe angles. A plan was devised by the DSN Telemetry Analysis Subgroup to select, gather, and analyze the required parameters. Two special data types were selected as inputs. The first consisted of special system noise temperature stripchart recordings. The second data type was the gathering of short periods of one-per-second doppler data and unfiltered automatic gain control (AGC). These data were gathered during times when the SEP angle was less than 15 degrees. The data were shipped to JPL and analyzed by the DSN Telemetry Analysis Subgroup.

Quick-look reports were distributed on each inferior conjunction finding. Preliminary conclusions were (1) the signal level (SL) degradation and the signal-to-noise ratio (SNR) degradation are due to decreased receiver loop SNR margin causing increased phase jitter, and (2) the experienced System Noise Temperature (SNT) correlates very closely with the predicted values.

The "Load and Go" station countdowns are still suspected to be a factor in the number of out-of-limits SL and SNR residuals. Not only Helios, but all projects are experiencing these difficulties.

IV. Conclusions

As the two Helios spacecraft speed past the Sun, the subsystems and experiments are performing well, sending to Earth valuable data about our solar system. Although each spacecraft has experienced some anomalies with TWTs, mission objectives and performance have not been degraded. The Helios-1 spacecraft ranging subsystem is functioning again and the Helios Project is looking forward to its fourth perihelion.

Agreements were published and interfaces established regarding DSN-STDN cross-support. A meeting at GSFC did much to smooth out engineering and operational difficulties. On-going efforts are continuing in the evaluation of the DSN-STDN cross-support data.

The Mu-2 ranging equipment will be prime at DSS 14. This equipment promises to give better resolution at very small Sun-Earth-Probe (SEP) angles, needed for Helios spacecraft Experiments 11 and 12.

The Helios-1 and Helios-2 inferior conjunctions provided an opportunity to gather data pertaining to 26-meter station performance during small SEP angles. Specific data were collected and will aid in the formulation of a performance model for better 26-meter performance predictions.

With the end of prime mission of Helios-2 (May 1976), the DSN tracking priority of both Helios spacecraft will equal that of Pioneers 10 and 11. This, coupled with Helios spacecraft distance from Earth being greater than 1 AU, will likely lead to a decrease in DSN tracking coverage. The telemetry recording threshold is almost reached using STDN stations, and little support can be expected from this source until September/October. However, the news that the German Government plans to modify the Weilheim Telecommand Station for receiving capability was very happily received by the Helios Project.

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2. Berman, A. L., "Doppler Noise Considered as a Function of the Signal Path Integration of Electron Density" in *The Deep Space Progress Report 42-33*. Jet Propulsion Laboratory, Pasadena, California (published in the present volume).

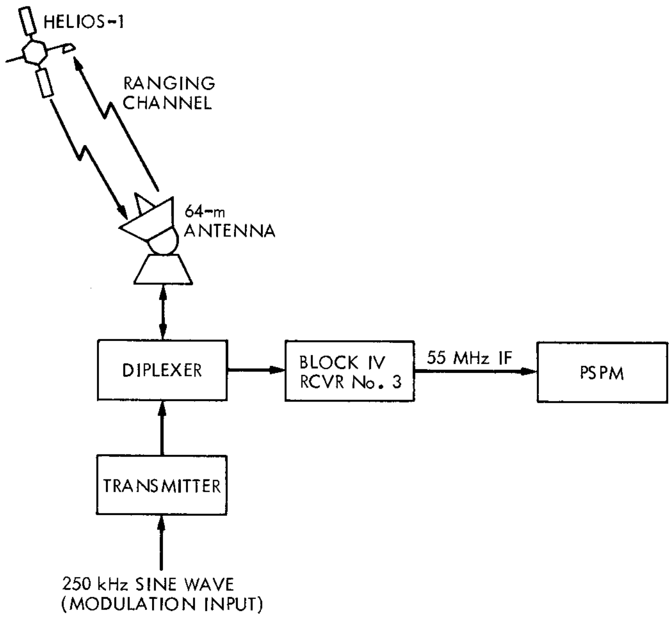

Fig. 1. Helios 1 ranging investigation (DSS 14), simplified system block diagram

	IMPLEMENTED AND TESTED BY
• INSTALLATION (INCLUDING TESTING) OF Mu-2 RANGING AT DSS 14	9 APRIL 1976
• END-TO-END DATA SYSTEM TEST	12 AND 13 APRIL 1976
• DEMONSTRATION PASS (HELIOS OR VIKING)	14 APRIL 1976
• OPERATIONAL SUPPORT WITH Mu-2 RANGING	15 APRIL 1976

Fig. 2. Implementation schedule for Mu-2 ranging support